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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:

Randall W. Roberts et al.

Serial No.: N/A

Examiner: Unknown

Filing Date: Herewith

Group Art Unit: Unknown

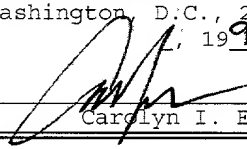
For: RESONANT RESPONSE MATCHING CIRCUIT FOR HEARING AID

Docket No.: 19210/106/101

TRANSMITTAL SHEET

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

<p>CERTIFICATE UNDER 37 C.F.R. 1.10: The undersigned hereby certifies that this paper or papers, as described herein, are being deposited in the United States Postal Service, "Express Mail Post Office to Addressee" having an Express Mail mailing label number of : <u>EM 077 053 486 US</u>, in an envelope address to: Assistant Commissioner for Patents, Washington, D.C., 20231 on this <u>17th</u> day of <u>February</u>, 19<u>99</u></p> <p>By <u></u> Carolyn I. Erickson</p>
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We are transmitting herewith the attached Patent Application including the following:

[XXXX] 10 sheet(s) of specification.

[XXXX] 5 sheet(s) of claim(s).

[XXXX] 1 sheet(s) of Abstract.

[XXXX] 4 sheet(s) of drawings.

[XXXX] Executed Declaration and Power of Attorney.

[XXXX] A verified statement(s) to establish small entity status under 37 C.F.R. 1.9 and/or 1.27 is enclosed.

[XXXX] An Assignment of the invention to Micro Ear Technology, Inc. d/b/a MICRO-TECH is being filed contemporaneous with this patent application.

[] A certified copy of a _____ application, serial no. _____, filed _____, 19____, the right of priority of which is claimed under 35 U.S.C. 119.

CLAIMS AS FILED						
	(1)	(2)	SMALL ENTITY		OTHER	
FOR:	# FILED	# EXTRA	Rate	Fee	Rate	Fee
BASIC FEE				\$380		\$760
TOTAL CLAIMS	20-20 =	0	x9=	\$ 0	x18=	\$
INDEPENDENT CLAIMS	4 -3 =	1	x39=	\$ 39	x78=	\$
() MULTIPLE DEPENDENT CLAIM PRESENTED			+130=	\$ 0	+260=	\$
TOTAL			\$419.00		\$	

*If the difference in Column (1) is less than zero, enter "0" in Column 2.

[XXXX] Other Recordation Form Cover Sheet-Patents Only

[XXXX] Checks in the amounts of \$419.00 and \$40.00 are enclosed.

[XXXX] Please charge any deficiencies or credit any overpayment in the enclosed fees to Deposit Account 14-0620.

By: Lawrence M. Nawrocki
 Lawrence M. Nawrocki
 Reg. No. 29,333

NAWROCKI, ROONEY & SIVERTSON, P.A.
 Suite 401, Broadway Place East
 3433 Broadway Street N.E.
 Minneapolis, Minnesota 55413
 Telephone: (612) 331-1464
 Facsimile: (612) 331-2239

Applicant or Patentee: Randall W. Roberts et al. Attorney's Docket No.: 19095/106/101

Serial or Patent No.: N/A

Filed or Issued: Herewith

For: RESONANT RESPONSE MATCHING CIRCUIT FOR HEARING AID

**VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY
STATUS (37 CFR 1.9(f) AND 1.27(c)) -- SMALL BUSINESS CONCERN**

I hereby declare that I am

- ☐ the owner of the small business concern identified below:
☒ an official of the small business concern empowered to act
on behalf of the concern identified below:

NAME OF CONCERN Micro Ear Technology, Inc. d/b/a MICRO-TECH

ADDRESS OF CONCERN _____

I hereby declare that the above-identified small business concern qualifies as a small business concern as defined in 13 CFR 121.3-18, and reproduced in 37 CFR 1.9(d), for purposes of paying reduced fees under section 41(a) and (b) of Title 35, United States Code, in that the number of employees of the concern, including those of its affiliates, does not exceed 500 persons. For purposes of this statement, (1) the number of employees of the business concern is the average over the previous fiscal year of the concern of the persons employed on a full-time, part-time or temporary basis during each of the pay periods of the fiscal year, and (2) concerns are affiliates of each other when either, directly or indirectly, one concern controls or has power to control the other, or a third party or parties controls or has the power to control both.

I hereby declare that rights under contract or law have been conveyed to and remain with the small business concern identified above with regard to the invention, entitled RESONANT RESPONSE MATCHING CIRCUIT FOR HEARING AID by inventor(s) Randall W. Roberts, David A. Preves and Mark A. Bren described in

- ☒ the specification filed herewith
☐ application serial no. _____, filed _____
☐ patent no. _____, issued _____

If the rights held by the above-identified small business concern are not exclusive, each individual, concern or organization having rights to the invention is listed below* and no rights to the invention are held by any person, other than the inventor, who could not qualify as a small business concern under 37 CFR 1.9(b) or by any concern which would not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e).

*NOTE: Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 CFR 1.27)

NAME _____

ADDRESS _____

☐ INDIVIDUAL ☐ SMALL BUSINESS CONCERN ☐ NONPROFIT ORGANIZATION

NAME _____

ADDRESS _____

☐ INDIVIDUAL ☐ SMALL BUSINESS CONCERN ☐ NONPROFIT ORGANIZATION

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b))

I hereby declare that all statements made herein of my own knowledge are true and that all statements

made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

NAME OF PERSON SIGNING David A. Preves

TITLE OF PERSON OTHER THAN OWNER Vice President, Research and Development

ADDRESS OF PERSON SIGNING 3500 Holly Lane North, Suite 10

Plymouth, Minnesota 55447

SIGNATURE David A. Preves DATE 2-16-99

RESONANT RESPONSE MATCHING CIRCUIT FOR HEARING AID

Background of the Invention

1. Field of the Invention -

The present invention relates generally to a circuit for
5 and method of processing an audio frequency signal and more
particularly relates to hearing aid signal processing.

2. Description of the prior art -

It is well known in the art to utilize electronic devices
to assist the hearing impaired. The earliest such instruments
10 consisted of a microphone coupled to an electronic amplifier
which was in turn coupled to an earphone. Quite apart from
the technical difficulties experienced, these early hearing
aids were sufficiently large and intrusive that the hearing
impaired could be readily identified providing a degree of
15 self-consciousness.

The coming of electronic miniaturization and sub-
miniaturization permitted the manufacture of hearing aid
systems which are totally inserted in the outer auditory canal
during use. The resulting systems provide substantially
20 greater hearing assistance along with a much more pleasing
(and almost unnoticeable) aesthetic appearance. A modern,
totally in-the-ear device has a microphone acoustically
coupled to the ambient with all of the electronics packaged in
a form factor which is accommodated by the outer ear of the

patient. A transducer is electronically coupled to the output stage of the hearing aid circuit and acoustically coupled to the distal portion of the outer auditory canal.

U.S. Patent No. 4,689,818, issued to Ammitzboll on August 5 25, 1987, purports to describe the circuitry and operation of the Siemens Custom In-The-Ear Hearing Aid 007, sold by Siemens Hearing Instruments, Inc. This is a typical example of a totally in-the-ear device.

A key problem in the miniaturization process is reducing 10 the size of the battery. Whereas substantial progress has been made in battery development, much credit is also appropriately given to designers of low power consumption electronic circuitry. Current state of the art instruments utilize class D output stages which are particularly helpful 15 in reducing overall power consumption. However, as is known to those of skill in the art, the class D output stage tends to have a frequency response curve whose peak gain frequency is not easily modified to accommodate differences in patient pathologies. Yet, abnormalities in middle ear functioning are 20 known to shift the peak in the unaided ear canal resonance to a lower frequency.

Summary of the Invention

The present invention overcomes the disadvantages of the prior art by providing a technique for utilizing the power saving characteristics of a class D output stage within a system which has sufficient adjustability in frequency response peak gain frequency to accommodate various differences in patient-to-patient middle ear pathology. Specifically, the present invention employs an active low-pass filter which has adjustable overshoot. This filter is coupled through a buffering stage to the class D output amplifier. By adjusting the degree of overshoot, the level of the peak in the frequency response of the entire system is readily adjustable within a given therapeutic range even though the class D output amplifier is inherently difficult to tune.

When practicing the present invention, the resonance curve of the outer auditory canal of the patient is determined utilizing existing techniques. This curve is relatively consistent for patients having normal ear physiology. However, various middle ear pathologies often lower the frequency of the basic resonance producing a unique frequency response curve for a given patient.

In accordance with the present invention, the overshoot of the low pass filter stage is adjusted such that the

frequency response curve of the hearing aid system most nearly matches the resonance curve of the patient's outer auditory canal. Thus, when the hearing aid is properly inserted, the resulting interface between the hearing assistance device and
5 the patient's middle ear are very closely correlated.

As a result of this frequency response match, the patient is provided with a smooth insertion frequency response without extra amplification at the frequency of the ear canal resonance. The advantages of lower power consumption,
10 lessened probability of acoustic feedback, and improved auditory acuity are the direct products of practicing the present invention.

In a preferred mode of practicing the present invention and not to be deemed to be limiting of the scope of the
15 invention, the output of the preamp or signal processing stage is applied to a standard R-C circuit. The resulting signal is coupled through a variable resistor to an amplifying stage, wherein the resistance variability adjusts the overshoot. The active low pass filter output is capacitively coupled to a
20 buffering stage employing a normal operational amplifier. The output of the buffering stage is applied directly to the class D output amplifier.

Brief Description of the Drawings

Other objects of the present invention and many of the attendant advantages of the present invention will be readily appreciated as the same becomes better understood by reference
5 to the following detailed description when considered in connection with the accompanying drawings, in which like reference numerals designate like parts throughout the figures thereof and wherein:

FIG. 1 is the 2cc coupler frequency response of a typical
10 ITE hearing aid with a class D output stage in the hearing aid receiver;

FIG. 2 are real ear IG frequency response curves in: a) the unoccluded outer auditory canal of a patient with normal middle ear function (REUR -- bottom) and b) with the hearing
15 aid of Fig. 1 (REAR -- top);

Fig. 3 is the response curve of Fig. 1 superimposed over the response curve shifted with the active low pass filter for a patient with abnormal middle ear pathology; and

Fig. 4 is a detailed electronic schematic diagram of the
20 signal processing circuit of the preferred mode of the present invention.

Detailed Description of the Invention

The present invention is described in accordance with several preferred embodiments which are to be viewed as illustrative without being limiting. In the preferred mode, the present invention is employed as a totally within the ear hearing aid system having a class D output stage.

Fig. 1 is diagram 10 showing the 2cc coupler frequency response of a typical ITE hearing aid with a class D output stage in the hearing aid receiver. Abscissa 14 is a logarithmic plot of frequency in kilohertz. Ordinate 12 shows the gain at each frequency plotted in decibels.

In a patient having normal middle ear physiology, the ear canal can be thought of as an open organ pipe having a primary resonance at about 2.8 kilohertz and a relatively flat response from about 300 hertz to about 3 kilohertz. As shown in diagram 10, gain curve 16 for the hearing aid is deliberately designed to match this response to replace the peak in gain lost when the ear canal is occluded by an ear mold. Gain peak 18 occurs at about 2.8 kilohertz.

Fig. 2 is diagram 11 showing the real ear IG frequency response curves in: a) the unoccluded outer auditory canal of a patient with normal middle ear function (bottom) and b) with the hearing aid of Fig. 1 (top). The bottom curve is a typical resonance curve of the unoccluded outer auditory canal (REUR) of a patient having normal middle ear physiology. Abscissa 17 is a logarithmic plot of frequency in kilohertz. Ordinate 19 shows the resonance at each frequency plotted in decibels. The top curve is the typical real ear output of the hearing aid of Fig. 1 in the ear canal whose unaided ear canal response is shown by the REUR curve.

As explained above, the ear canal can be thought of as an open organ pipe having a primary resonance at about 2.8 kilohertz and a relatively flat response from about 300 hertz to about 3 kilohertz. As shown in diagram 11, REUR curve 15 shows the resonance curve for the typical patient. Resonance peak occurs at about 2.8 kilohertz.

For a hearing impaired patient having a totally in-the-ear hearing aid device, the outer auditory canal is totally or partially blocked thus removing the natural resonance at resonance peak 18. However, it is typical that the class D amplifiers employed in current devices deliberately have a

corresponding response peak at about 2.8 kilohertz (see also Fig. 1). Thus, the totally in-the-ear hearing aid device having the class D amplifier can easily provide hearing assistance with a response similar to the non-hearing
5 impaired ear as shown by REAR curve 13.

Fig. 3 is a diagram 20 showing a 2cc coupler response curve 16 of Fig. 1 superimposed upon shifted response curve in a 2cc coupler 22 for a patient having a typical middle ear pathology which lowers the primary resonance of resonance
10 curve 22 to resonance peak 24. For this example, peak 24 occurs at about 1.2 kilohertz.-8--8-

A number of various problems can cause this lowering of the resonance of the outer auditory canal including punctured ear drum, abnormal middle ear bone physiology, etc. If a
15 standard totally in-the-ear hearing aid device, having a class D output amplifier, is utilized in the patient of resonance curve 22, there will be a substantial mismatch in the frequency response curve of the hearing aid device and that of the open ear of the patient.

20 This mismatch renders most hearing aids incapable of providing enough amplification at the abnormally low resonant peak of frequency of the patient. The result is under-

amplification at this frequency and a jagged insertion gain frequency response.

Fig. 4 is a detailed electronic schematic diagram 26 showing the critical circuitry of the preferred mode of the present invention. To properly practice the invention, the unaided ear canal resonance curve (REUR) of a given patient is obtained by measurement in accordance with standard procedures and the circuit of the present invention is tuned to match this measured resonance curve, before the device is released to the patient for use.

Microphone 28 is a standard hearing aid microphone acoustically coupled to the ambient. The signal produced by microphone 28 is coupled through standard preamplifier 20 and standard signal processing stage 31 to the low pass filter consisting of resistor 30 and capacitor 32. Variable resistor 38 couples the filtered signal to operational amplifier 42 and forms another pole of the low pass filter with capacitor 40. In this way, variable resistor 38 controls the amplification gain of the overshoot and the peak frequency of the low pass filter. Thus, variable resistor 38 controls frequency of peak gain in the frequency response curve of the entire hearing aid system.

The processed audio frequency signal is capacitively coupled via capacitor 44 to operational amplifier 50 via resistor 46. Resistor 48 provides feedback for operational amplifier 50 which functions as a buffering stage between the
5 active low pass filter stage and the class D output amplifier.

The output of operational amplifier 50 is capacitively coupled via capacitor 52 to standard class D output amplifier 54.

Having thus described the preferred embodiments of the
10 present invention, those of skill in the art will be readily able to adapt the teachings found herein to yet other embodiments within the scope of the claims hereto attached.

It will be understood that this disclosure, in many respects, is only illustrative. Changes may be made in
15 details, particularly in matters of shape, size, material, and arrangement of parts without exceeding the scope of the invention. Accordingly, the scope of the invention is as defined in the language of the appended claims.

What is claimed is:

1. In an electronic device for use in assisting a hearing impaired patient having a microphone, a preamp, a signal processing stage, and an output amplifier, the improvement comprising:

a. an active low pass filter responsively coupled between said signal processing stage and said output amplifier having an adjustable overshoot.

2. The improvement of claim 1 wherein said output amplifier further comprises a class D amplifier.

3. The improvement of claim 2 further comprising a buffer stage responsively coupled intermediate said active low pass filter and said output amplifier.

4. The improvement of claim 3 wherein said hearing impaired patient has an outer auditory canal with a resonance curve and wherein said adjustable overshoot is sufficient to match the pass band of said electronic device to correspond to said resonance curve.

5. The improvement of claim 4 wherein said active low pass filter further comprises a variable resistor to provide said adjustable overshoot.

6. An apparatus comprising:

- a. a microphone;
- b. a preamp and signal processing stage responsively coupled to said microphone;
- b. an active low pass filter responsively coupled to said preamp and signal processing stage; and
- c. an output amplifier responsively coupled to said active low pass filter.

7. An apparatus according to claim 6 wherein said output amplifier further comprises a class D amplifier.

8. An apparatus according to claim 7 wherein said active low pass filter further comprises a component for adjusting the overshoot of said active low pass filter.

9. An apparatus according to claim 8 wherein said component adjusts the peak frequency of said active low pass filter.

10. An apparatus according to claim 9 wherein said component further comprises a variable resistor.

11. A method of assisting a hearing impaired patient comprising:

- a. measuring the resonance curve of the outer auditory canal of said hearing impaired patient;
- b. tuning the frequency response curve of an electronic hearing aid to correspond to with the measured resonance curve; and
- c. inserting said tuned electronic hearing aid into the ear of said hearing impaired patient.

12. A method according to claim 11 wherein said electronic hearing aid further comprises a class D output amplifier.

13. A method according to claim 12 wherein said electronic hearing aid further comprises an active low pass filter responsively coupled to said class D output amplifier.

14. A method according to claim 13 wherein said tuning step further comprises adjusting the overshoot of said active low pass filter.

15. A method according to claim 14 wherein said adjusting further comprises adjusting a variable resistor.

16. An apparatus comprising:

- a. means for converting an acoustic signal into an electrical signal;
- b. means responsively coupled to said converting means for adjustably processing said electrical signal to produce a desired frequency response; and
- c. means responsively coupled to said processing means for amplifying said processed electrical signal.

17. An apparatus according to claim 16 wherein said amplifying means further comprises a class D amplifier.

18. An apparatus according to claim 17 wherein said processing means further comprises an active low pass filter.

19. An apparatus according to claim 18 wherein said active low pass filter further comprises means for adjusting the overshoot.

20. An apparatus according to claim 19 wherein said adjusting means further comprises a variable resistor.

Abstract of the Disclosure

An apparatus for and method of employing an electronic hearing aid device to assist a hearing impaired patient. The resonance curve of the outer auditory canal of the patient is determined. A device in accordance with the present invention is tuned to a frequency response curve which matches the measured resonance curve. The device is tuned by adjusting the overshoot of a low pass filter stage which is interposed between the microphone input and a class D output stage.

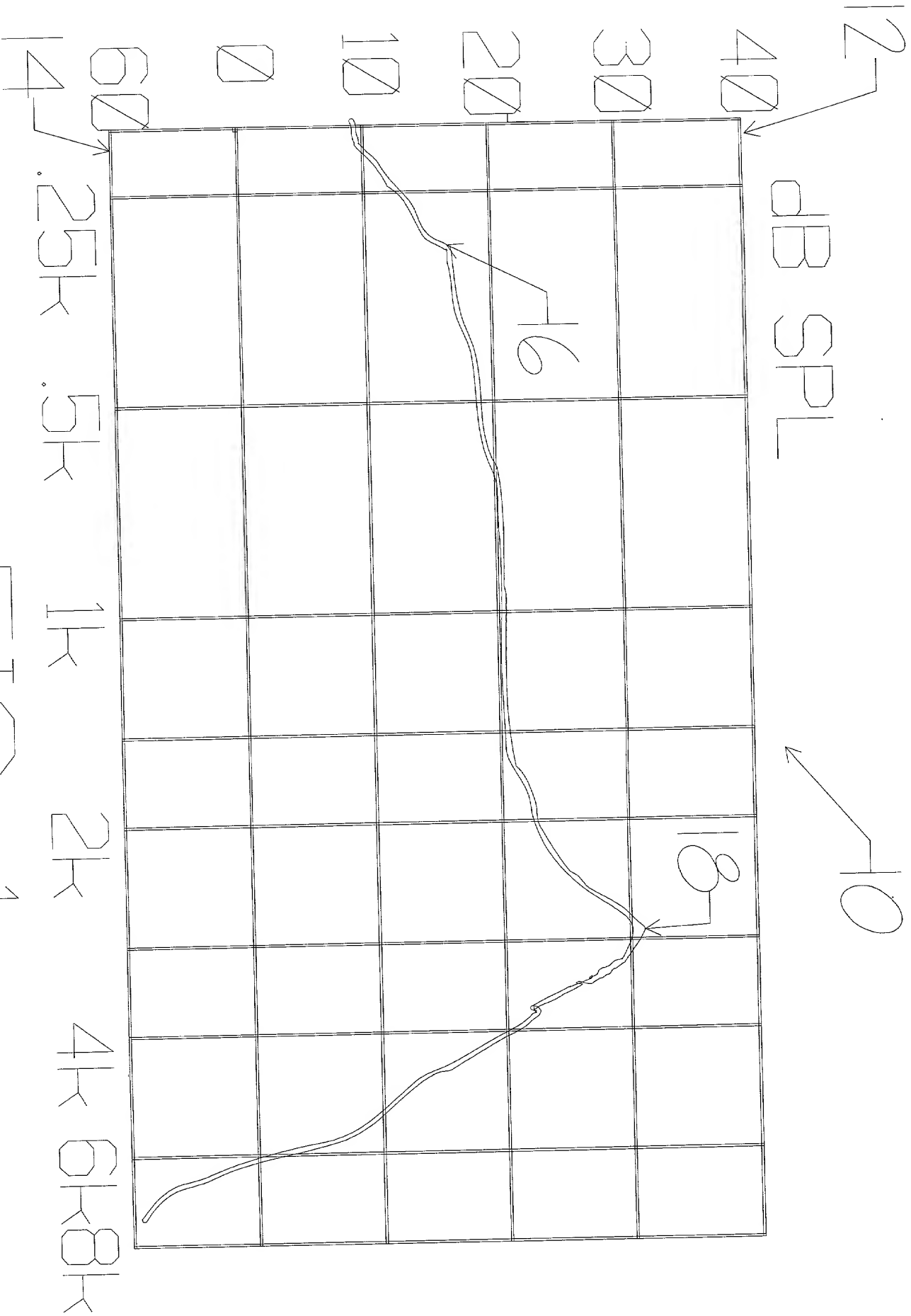
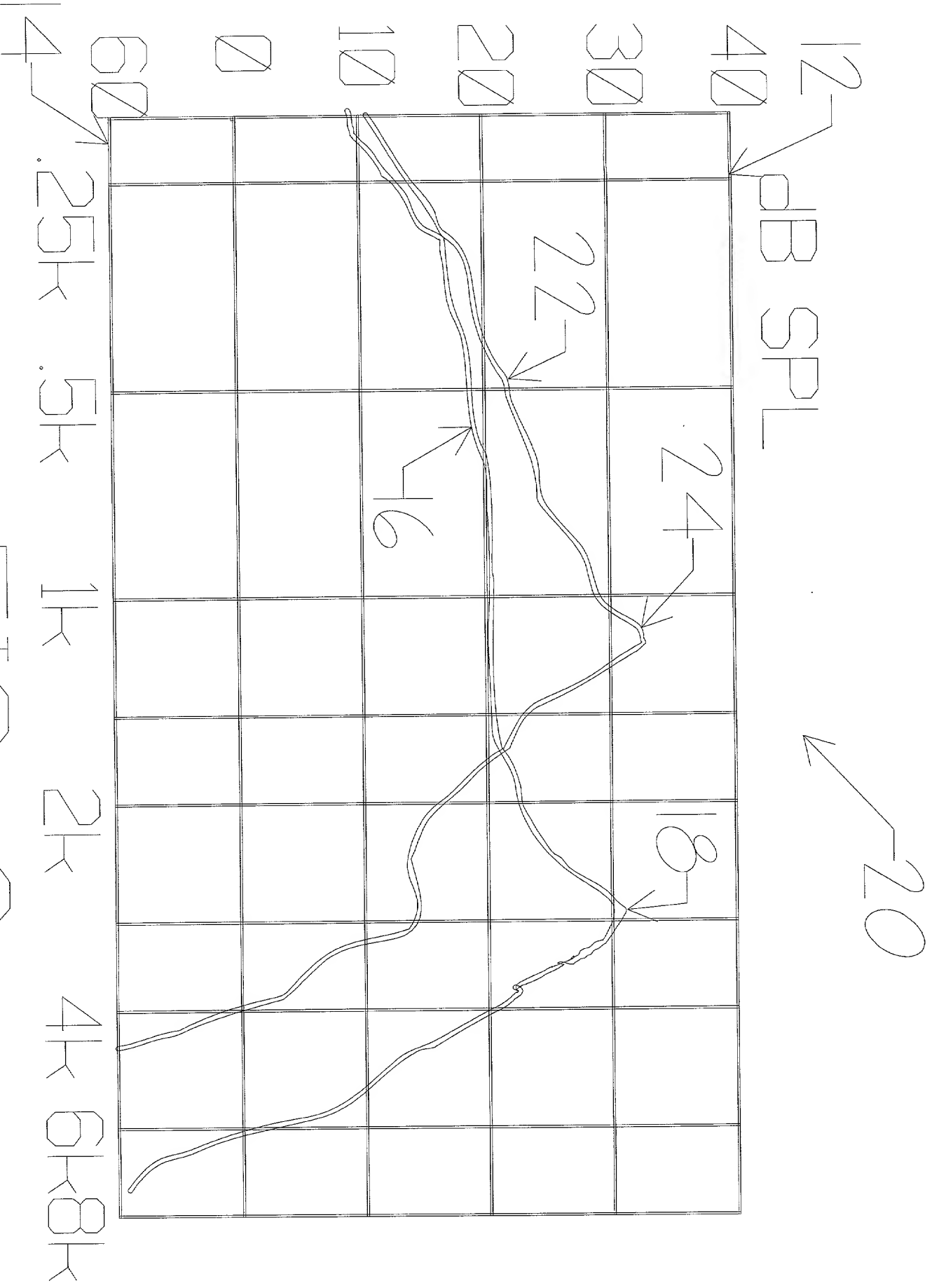
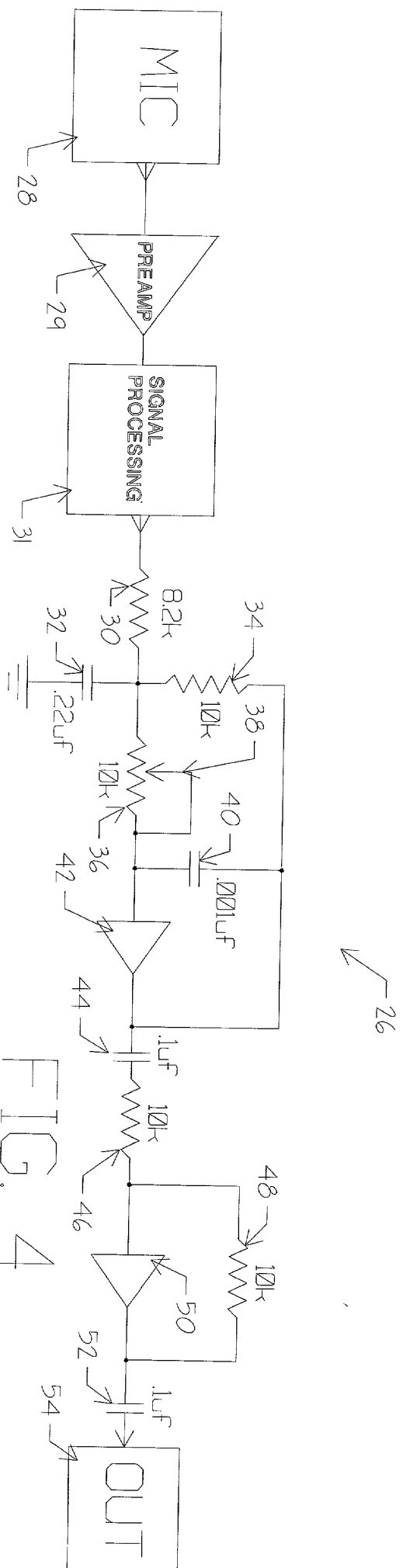


FIG 1



ETG 3

[illegible]

COMBINED DECLARATION/POWER OF ATTORNEY FOR PATENT APPLICATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe that I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled RESONANT RESPONSE MATCHING CIRCUIT FOR HEARING AID, the specification of which (check one)

XX is attached hereto

___ was filed on _____
as U.S. Application
Serial No. _____

___ and was amended on (if
applicable) _____

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

I hereby claim foreign priority benefit(s) under Title 35, United States Code §119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application(s) for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)			Priority Claimed	
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	_____ YES	_____ NO
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	_____ YES	_____ NO
_____ (Number)	_____ (Country)	_____ (Day/Month/Year Filed)	_____ YES	_____ NO

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner

provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

(Serial No.)	(Filing Date)	(Status) (patented, pending, abandoned)
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(Serial No.)	(Filing Date)	(Status-patented, pending, abandoned)
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POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

John L. Rooney, Reg. No. 28,898;
Lawrence M. Nawrocki, Reg. No. 29,333;
Wayne A. Sivertson, Reg. No. 25,645;
Erik O. Berger, Reg. No. P42,315; and
Donald A. Jacobson, Reg. No. 22,308

Send correspondence to:

Lawrence M. Nawrocki
NAWROCKI, ROONEY & SIVERTSON, P.A.
Suite 401, Broadway Place East
3433 Broadway Street Northeast
Minneapolis, Minnesota 55413
(612) 331-1464

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon, I further declare that I understand the content of this declaration.

Full name of sole or first inventor Randall W. Roberts
Inventor's Signature *Randall W. Roberts* Date 2/15/99
Residence 17640 Lorence Way
Eden Prairie, Minnesota 55346 Citizenship U.S.A.
Post Office Address 17640 Lorence Way
Eden Prairie, Minnesota 55346

[illegible]

Full name of third or joint inventor Mark A. Bren
Inventor's Signature Mark A Bren Date 2-16-99
Residence 23531 County Road 10
Laretto, Minnesota 55357 Citizenship U.S.A.
Post Office Address 23531 County Road 10
Laretto, Minnesota 55357

1.56 Duty to disclose information material to patentability.

(a) A patent by its very nature is affected with a public interest. The public interest is best served, and the most effective patent examination occurs when, at the time an application is being examined, the Office is aware of and evaluates the teachings of all information material to patentability. Each individual associated with the filing and prosecution of a patent application has a duty of candor and good faith in dealing with the Office, which includes a duty to disclose to the Office all information known to that individual to be material to patentability as defined in this section. The duty to disclose information exists with respect to each pending claim until the claim is cancelled or withdrawn from consideration, or the application becomes abandoned. Information material to the patentability of a claim that is cancelled or withdrawn from consideration need not be submitted if the information is not material to the patentability of any claim remaining under consideration in the application. There is no duty to submit information which is not material to the patentability of any existing claim. The duty to disclose all information known to be material to patentability is deemed to be satisfied if all information known to be material to patentability of any claim issued in a patent was cited by the Office or submitted to the Office in the manner prescribed by §§1.97(b)-(d) and 1.98. However, no patent will be granted on an application in connection with which fraud on the Office was practiced or attempted or the duty of disclosure was violated through bad faith or intentional misconduct. The Office encourages applicants to carefully examine:

- (1) prior art cited in search reports of a foreign patent office in a counterpart application, and
- (2) the closest information over which individuals associated with the filing or prosecution of a patent application believe any pending claim patentably defines, to make sure that any material information contained therein is disclosed to the Office.

(b) Under this section, information is material to patentability when it is not cumulative to information already of record or being made of record in the application, and

- (1) It establishes, by itself or in combination with other information, a prima facie case of unpatentability of a claim; or
- (2) It refutes, or is inconsistent with, a position the applicant takes in:
 - (i) Opposing an argument of unpatentability relied on by the Office, or
 - (ii) Asserting an argument of patentability.

A prima facie case of unpatentability is established when the information compels a conclusion that a claim is unpatentable under the preponderance of evidence, burden-of-proof standard, giving each term in the claim its broadest reasonable construction consistent with the specification, and before any consideration is given to evidence which may be submitted in an attempt to establish a contrary conclusion of patentability.

(c) Individuals associated with the filing or prosecution of a patent application within the meaning of this section are:

- (1) Each inventor named in the application;
 - (2) Each attorney or agent who prepares or prosecutes the application; and
 - (3) Every other person who is substantively involved in the preparation or prosecution of the application and who is associated with the inventor, with the assignee or with anyone to whom there is an obligation to assign the application.
- (d) Individuals other than the attorney, agent or inventor may comply with this section by disclosing information to the attorney, agent, or inventor.